AD-A282 527



AIBIS

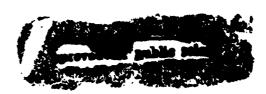
# **Quarterly Report**

Analysis of Cost:
Combustion Flame CVD Diamond Deposition

Contract Number: N00014-93-C2044



42<sup>457</sup>**94-23359** 



IBIS Associates, Inc. 55 William Street, Suite 220 Wellesley, MA 02181-4003 USA

94 7 25 004

# 3

# **Quarterly Report**

Analysis of Cost:
Combustion Flame CVD Diamond Deposition

Contract Number: N00014-93-C2044

Distribution Statement A: Approved for Public Release: Distribution is Unlimited.



Second Quarter 1994

IBIS Associates, Inc. 55 William Street, Suite 220 Wellesley, MA 02181 Tel: 617-239-0666

Fax: 617-239-0852

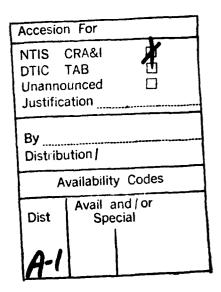
### **Executive Summary**

IBIS Associates has improved its predictive spreadsheet model of combustion flame chemical vapor deposition (CVD) diamond film fabrication. This report explains the improvements on the combustion flame deposition theory, and shows preliminary results of the economics of this CVD diamond process.

The changes to the model include the incorporation of thermal conductivity as an input to the model, allowing the user to specify the thermal properties of the diamond being formed. Also, the deposition theory in the model has been streamlined with the assistance of diamond deposition experts. Numerous inputs have been eliminated in this process, making the model easier to use.

For this report and the results contained herein, it is assumed that the transport theory model which predicts growth rates in the CVD diamond technical cost model closely predicts actual growth rates for the combustion flame technology and that the input values for variables such as the gas flow rate and substrate diameter are physically achievable.

To be investigated are alternative combustion flame deposition geometries and chemistries. Expert review has revealed that the deposition geometry assumptions (i.e. nozzle:substrate diameter ratio) in the IBIS model may not be optimal for combustion flame deposition. Suggested changes in deposition geometries involve the size, shape, and distance to substrate of the combustion nozzle, as well as higher flow rates at smaller nozzle sizes. Suggested changes in deposition chemistry include using ethylene as the carbon fuel instead of acetylene. Lastly, expert approval of the models is continually in progress.



## **Combustion Flame TCM Expert Review**

The combustion flame CVD diamond Technical Cost Model (in the Appendix) has been reviewed by deposition experts representing Sandia National Laboratories in both Albuquerque, NM and Livermore, CA; Stanford University; Caltech; and Lockheed. Copies of the model were transfered to these theorists along with a non-transferable site license, and all were tutored on the Technical Cost Modeling methodology. A thorough expert review of the combustion flame model was undertaken during this tutorial. In response to the model criticism that surfaced, a plan for the revision of the cost model was drafted.

The expert review of the combustion flame CVD diamond cost model produced no significant criticisms. There was a concensus among the theorists that two of the three quality measures, as reported in the first quarter report for 1994, are unnecessary. The model has been streamlined to use only one of the quality measures (H/CH3), which is believed to correlate the closest to thermal conductivity.

A defect-based model of CVD diamond material properties has been developed by Michael Coltrin at Sandia National Laboratories and David Dandy at Colorado State University. Inputs to this model include the hydrogen (H) and methyl radical (CH3) mole fractions at the growth surface, as well as numerous rate constants for the reactions considered at the growth surface. Outputs of this model include the growth rate and defect density, which are used to determine thermal conductivity. IBIS generated data from this model and performed regression analysis in order to find the H/CH3 ratio as a function of thermal conductivity. As shown later in this report, the relationship assumed to exist between H/CH3 and the thermal conductivity of the CVD diamond allows thermal conductivity to exist as an input to the cost model.

The model's shortcomings were identified by the experts as its inability to predict the effects of changing in reactor pressure, fuel chemistry, or nozzle count. The concensus was reached that a new version of the model should be developed with the ability to predict changes in these three conditions. Due to the large amount of data required to derive predictive relationships for all these processing parameters and the nonexistance of this data in the public domain, a plan for data collection from numerical models was established. As agreed, all organizations involved in the expert review with the exception of Lockheed will cooperate in the data generation.

### **Sensitivity Analysis**

Technical Cost Modeling permits the flexibility of performing sensitivity analyses. Using sensitivity analyses, it is possible to explore the cost implications of changing key input variables such as gas composition, production volume, material prices, product dimensions, etc. As an R&D management tool, these analyses help set development goals for cost effective manufacturing. Further, they help in long term planning, by indicating the cost savings that may be realized through scale-up. For the purpose of these sensitivity analyses it is assumed that the transport theory model which is used to estimate the diamond growth rate closely predicts actual growth rates and that the input values for variables such as gas flow rate and substrate temperature are physically achievable. Presented in the following sections are the following analyses, all based on the assumption of thermal management quality diamond:

- Cost vs Substrate Diameter and Gas Consumption
- Cost vs Thermal Conductivity and Gas Ratio
- Cost vs Thermal Conductivity and Substrate Diameter

For all of these analyses, the ratio of substrate to duct area is held constant. This constraint is due to the geometry assumed for the combustion flame technology as modeled (i.e., a single nozzle torch). The area of the gas duct is the cross-sectional area of the flame before it is affected by the flow pattern around the substrate. For a combustion flame with a corresponding duct area impinging on an infinite plane, there will be a circular region of desirable diamond and a surrounding region of unacceptable diamond. Consider the similar case of a flame impinging on a substrate of the same area. As a substrate diameter increases while the duct diameter remains constant, there is a point at which the substrate extends into this zone of unacceptable diamond. Therefore, there is a maximum substrate:duct area ratio that should not be exceeded. Experts in CVD diamond deposition suggest that this ratio is roughly 3:1 for single nozzle torches. When the substrate diameter is varied in the following analyses, the duct diameter is adjusted so that the ratio of substrate to duct area is constant.

### Cost vs Substrate Diameter and Gas Consumption

Figure 1 shows the combustion flame deposition cost per square centimeter of one millimeter thick polycrystalline diamond varying with the diameter of the deposited wafer. In addition, because the duct area and gas flow rate increase with substrate area, Figure 1 shows the total gas flow rate changing with the substrate diameter. The volumetric gas flow rate must change with the duct diameter, if constant quality is to be maintained, due to the assumptions in deposition theory that are mentioned in the first quarter report of 1994. At about nine centimeters in diameter, the cost per square centimeter of combustion flame CVD diamond reaches a minimum of roughly \$60. The incorporation of the gas flow rate plot illustrates why there exists an optimum substrate diameter: as the duct area increases to

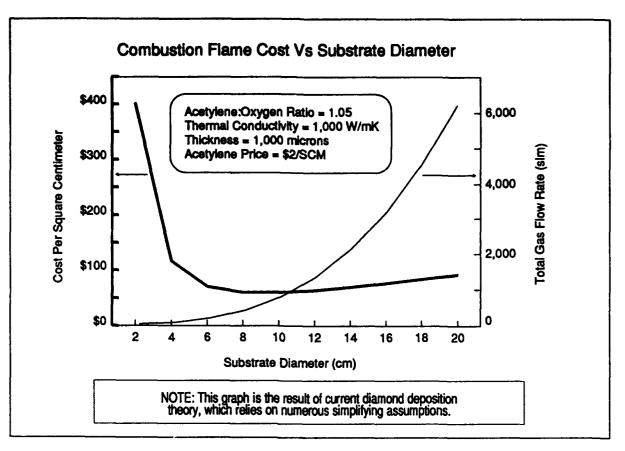


Figure 1

maintain the substrate to duct area ratio, the volumetric gas flow rate must also increase to sustain the same strain rate parameter (same quality diamond). Therefore, the economy of scaling the substrate diameter peaks at about nine centimeters, above which the required gas flow increases the cost.

### Cost vs Thermal Conductivity and Gas Ratio

The effect of quality, in terms of thermal conductivity, on CVD diamond deposition cost at different gas ratios can be seen in Figure 2. The reason for the rise in cost with thermal conductivity relates to the correlation between purity and thermal conductivity. For this simulation, the purity of diamond is assumed to depend on the ratio of atomic hydrogen to methyl radicals at the growth surface; this model predicts that thermal conductivity will increase with this ratio. Increasing the ratio of atomic hydrogen to methyl radicals, while keeping the proportion of acetylene to oxygen flow constant, requires an increase in the flow rate of the inlet gases. As shown in Figure 1, increasing flow rates leads to rising costs. From Figure 2, higher thermal conductivity diamond (1,000 to 1,500 W/mK) should be grown at lower ratios of acetylene to oxygen, dropping the cost by a factor of four when lowering this ratio from 1.10 to 1.02 at 1,500 W/mK. Also shown in Figure 2 is the cost of thermal conductivity. CVD diamond grown to achieve 1,000 W/mK thermal conductivity costs about an order of magnitude less than diamond with 1,500 W/mK thermal

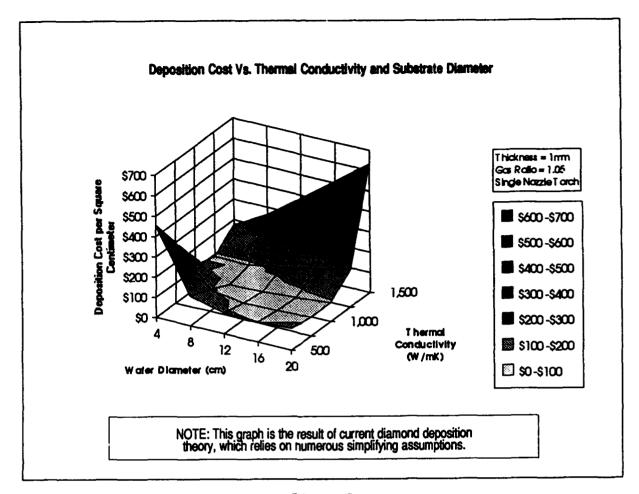


Figure 3

### **Conclusions**

IBIS Associates has improved its predictive spreadsheet model of combustion flame chemical vapor deposition (CVD) diamond film fabrication. This report explains the improvements on the combustion flame deposition theory, and shows preliminary results of the economics of this CVD diamond process.

The changes to the model include the incorporation of thermal conductivity as an input to the model, allowing the user to specify the thermal properties of the diamond being formed. Also, the deposition theory in the model has been streamlined with the assistance of diamond deposition experts. Numerous inputs have been eliminated in this process, making the model easier to use.

For this report and the results contained herein, it is assumed that the transport theory model which predicts growth rates in the CVD diamond technical cost model closely predicts actual growth rates for the combustion flame technology and that the input values for variables such as the gas flow rate and substrate diameter are physically achievable.

To be investigated are alternative combustion flame deposition geometries and chemistries. Expert review has revealed that the deposition geometry assumptions (i.e. nozzle:substrate diameter ratio) in the IBIS model may not be optimal for combustion flame deposition. Suggested changes in deposition geometries involve the size, shape, and distance to substrate of the combustion nozzle, as well as higher flow rates at smaller nozzle sizes. Suggested changes in deposition chemistry include using ethylene as the carbon fuel instead of acetylene. Lastly, expert approval of the models is continually in progress.

# **Appendix**

-	r
700	h
đ	۸
-	4
	2
	j
Ĭ	
i	ď
:	j
į	5
	_
7	3
7	í
ċ	J
•	٠

PRODUCT SPECIFICATIONS			111111111111111111111111111111111111111		,							
RODUCT SPECIFICATIONS	Revision Date: 6/30/	te: 6/30/94		GAS [	DATABASE			Price		No. of ount/Mo	Mo. Tank	Price
7 0 1 1 1 6 A 1 1 1 6 6	:			•	Gas	Source	Purity	\$/SCM	Carbons	SCA	Rental	Update
TOTCH TYPE SINGLE NOZZIE	atzzon erbut			•	. Cack	• • • • • • • • • • • • • • • • • • •		00 08	2	00740		
Mafor Disactor	o in. substrate	P. (	NAME		androadur m.	4	********	20.00	9 6	35.404	070 68	1/03
recent the repeated to the second		5 9	STORE STORE		tq nydrogen	O TTU		40.54	9 6	45104	62,070	2/10
Theres Conductivity		W./20	NOOMBER			27,4		20.00	8 6	10.401	54 500	1/93
יוופרווימד כסוומתכרוואדרא		/ III /	TUERMICON		I da Argon	A LACO		51.50	8 8	20434	0000	1/93
Annual Production Volume		(40/000/ 0 1		rv	Lin Argon	4110		51.32		25.404	8920	1/93
Tenath of Droduction Bun		111 (200	DI TEE	v	CODY PIL	2011		\$1.20	9 6	35404	200	1/02
הפוולכיו כד בדסמהכרדסון עמון		γιs	ruite	9 6	mobile bin	Date on		52.1¢	3 6	00100	27, 300	1/03
MOTHER CERTIFIC TO SOUTH A SOU				۰ ۰	nydrogen	MG Tad	9000000	640.61	9 6	200		20/
NOCESS RELATED FACTORS - SURFAC	CE PREPARATI	;		0 0	liyarogan	. Tug.	10000 00	20.012	8	200		7 / 7 2
Sesour seedora			USEI	, ,	nyarogen	DUT OF	920.00	97.016		00.400		76/7
Dealcated Investment		N-O X-T	1030	2 :	нуагодеп	ALE PEOG.	30.66	60.14	0.00	05+00		1/83
Process Yield	95.04		YLDI	11	Argon	MG Ind	**************************************	\$33.09	0.00	00+30		1/93
Average Equipment Downtime	20.04		DOWN1	12	Argon		\$1666.66	\$37.33	0.00	0E+00		1/93
Direct Laborers Per Station	0.50		NLAB1	13	Argon	Air Prod.	\$666°66	\$11.74	0.0	0E+00		1/93
				14	Argon	Air Prod.	99.997₩	\$2.03	0.00	0E+00		1/93
Substrate Material	11	[menu #]	MATL1	15	Methano	Alr Prod.	166.66	\$21.99	1.00	0E+00		1/93
Pieces Per Batch		Des/batch	PCS1	16	Methane	Air Prod.	<b>\$</b> 66	\$13.76	1.00	0E+00		1/93
det F sagoord		min/hetch	DTTME	12	Mothana	Air prod	938	54.93	00	00+30		1/03
Building Space Demirement		acet /ets	F101	9	A Cotto land	Air prod	49 66	02 95		00+40		1 / 03
and all the same and a first the		B16/14	t and	9 6	Acetylene Acetylene	Air Brod	90	65.20				200
				1 0	0101111111	, , , , , , , , , , , , , , , , , , ,			3 6			
FROCESS RELATED FACTORS - DEPOSITION	1	;	•	0 ;	Acetylene	ripetine	BC - 0K	\$2.00	2.00	05+00		7/82
Process In Use?		[N-0 X-I]	USEZ	21	Hellum	Air Prod.	90555.65	\$15.90	00.0	00+30		1/93
Dedicated Investment		(1-Y 0-N)	DED2	22	Helium	Air Prod.	99.992#	54.77	0.00	0E+00		1/93
Process Yield	87.5		YLD2	23	Nitrogen	Air Prod.	\$9666.66	\$45.50	0	0E+00		1/93
Average Equipment Downtime	15.04		DOWN2	24	Nitrogen	MG Ind.	\$666°66	\$9.23	0.0	0E+00		1/93
Direct Laborers	0.40	/sta	NLAB2	25	Nitrogen	Air Prod.	\$866.66	\$1.24	0.0	0E+00		1/93
				56	Lig Oxygen	Air Prod.	99.54	\$0.21	0.0	1E+00	\$350	1/93
Machine Power	7	ΧW	POW2	27	Oxygen	Air Prod.	99.54	\$0.58	0.00	0E+00		1/93
Machine Load/Unload Time		min/batch	PTTME2		•							
Available Denosition Time		hre/cr	DAVED 2									
		1 / / I / O / O / O										
Hadra Mellovat via Substitute	90.00	Teror I	H.I.K.W.Z									
Coordant Temp. Kise			TEMPZ									
Heat Capacity of Coolant		cal/g/c	CP2									
Bullding Space Requirement	1,500 8	sqft/sta	FLR2					1		İ		
				SUBS	SUBSTRATE DATABASE		Price	Thick	Diam		LIL	Price
Acetylene:Oxygen Ratio (R)		[1.02 <x<1.1]< td=""><td></td><td>•</td><td>Substrate</td><td>Source</td><td>2/69</td><td>5</td><td>5</td><td>um/min</td><td></td><td>Update</td></x<1.1]<>		•	Substrate	Source	2/69	5	5	um/min		Update
Oxygen		[menc ♠]	GASA2	1							1111111	
Acetylene	50	[menc #]	GASB2	0	None		\$0.00	-	1.00	1.00	1.00	
					Silicon	S1-Toch	\$2.65	1270.00	5.08	20.00	~	1/93
Oxygen Recycle Rate	0.0		RECYC2A	~	Silicon	S1-Tech	\$3.50	1270.00	7.62	20.00	-	1/93
Carrier Gas Recycle Rate	0.0		RECYC2B	m	Silicon	S1-Tech	\$6.25	1270.00	10.16	20.00	-	1/93
Gas Recycle Equipment Cost		total	MCH2A	4	Silicon	S1-Tech	89.70	1270.00	12.70	20.00	-	1/93
				ur.	Silicon	Si-Tech	v	1270.00	15.24	20.00	-	1/93
Growth Correction Factor (f)	0.50		60.50	. 42	Stiteon	St-Tach		1270.00	20.32	20.00	-	1/63
Substrate:Duct Area Batto		[1 <x<=4]< td=""><td>STIBDITC2</td><td>, ~</td><td>S111con</td><td>S1-Tech</td><td></td><td>3810.00</td><td>5.08</td><td>20.00</td><td>۰-</td><td>1/93</td></x<=4]<>	STIBDITC2	, ~	S111con	S1-Tech		3810.00	5.08	20.00	۰-	1/93
Substrate Distance-Duct Diam		[0<*<=10]	1.02	α	2111000	TO TIE		3810.00	7.62	20.00		1/63
		101-1410		0	S11100	T-TO-T-	914 50	2810.00	10 16	20.02	٠.	- 1
	Ş			, 5	1001170	4000-10	622 65	00.0195	200			20/1
Weess nemated racions - Elenia	2			2	1001116	TOPT - TO		00.000		20.00	•	

Si-Tech \$43.45 3810.00 15.24 20.00 1 1/93 Si-Tech \$135.20 3810.00 20.32 20.00 1 1/93 Si-Tech \$6.85 6350.00 5.08 20.00 1 1/93 Si-Tech \$12.80 6350.00 7.62 20.00 1 1/93 Si-Tech \$22.75 6350.00 10.16 20.00 1 1/93 Si-Tech \$35.55 6350.00 12.70 20.00 1 1/93	Tech \$48.30 6350.00 15.24 20.00 1 Tech \$48.20 6350.00 15.24 20.00 1 Limet \$8.20 254 5.08 10.00 1.00 Limet \$14.50 254 10.16 10.00 1.00 Corp \$25.35 254 10.00 1.00 Corp \$4.40 508.00 5.08 10.00 4 Corp \$44.75 508.00 15.24 10.00 4	Corp \$37.10 508.00 20.32 10.00 4  Elmet \$9.15 1524.00 5.08 10.00 20  Corp \$27.60 1524.00 10.16 10.00 20  Corp \$12.25 1524.00 15.24 10.00 20  Corp \$14.75 2286.00 5.08 10.00 32.00  Corp \$69.00 2286.00 10.16 10.00 32.00  Corp \$69.00 2286.00 15.24 10.00 32.00  Corp \$13.50 2286.00 15.24 10.00 32.00  Corp \$46.75 3175.00 10.16 10.00 46.00  Corp \$46.75 3175.00 10.16 10.00 46.00  Corp \$199.00 3175.00 20.32 10.00 46.00	Les Corp \$7.75 254 5.08 10.00 1.09  Les Corp \$24.75 254 10.16 10.00 1.00 1/93  Les Corp \$79.25 254 10.16 10.00 1.00 1/93  Les Corp \$79.25 254 10.00 1.00 1/93  Les Corp \$10.00 508.00 5.08 10.00 4.00 1/93  Les Corp \$35.10 508.00 10.16 10.00 4.00 1/93  Les Corp \$67.00 508.00 10.16 10.00 4.00 1/93  Les Corp \$109.20 508.00 15.24 10.00 4.00 1/93  Les Corp \$112.00 1524.00 5.08 10.00 20.00 1/93  Les Corp \$112.00 1524.00 10.16 10.00 20.00 1/93  Les Corp \$112.00 1524.00 10.16 10.00 20.00 1/93  Les Corp \$112.00 1524.00 10.16 10.00 20.00 1/93  Les Corp \$112.00 1524.00 15.24 10.00 46.00 1/93  Les Corp \$60.00 3175.00 15.24 10.00 46.00 1/93  Les Corp \$521.30 3175.00 15.24 10.00 46.00 1/93  Les Corp \$687.00 3175.00 20.32 10.00 46.00 1/93  Les Corp \$687.00 3175.00 20.32 10.00 46.00 1/93	
11 Silicon 12 Silicon 13 Silicon 14 Silicon 15 Silicon	Silicon Silicon Silicon Silicon Molybdenum Molybdenum Molybdenum Molybdenum Molybdenum Molybdenum		19 Tungsten logies 40 Tungsten logies 41 Tungsten logies 43 Tungsten logies 44 Tungsten logies 45 Tungsten logies 46 Tungsten logies 47 Tungsten logies 48 Tungsten logies 50 Tungsten logies 51 Tungsten logies 52 Tungsten logies 53 Tungsten logies 54 Tungsten logies 55 Tungsten logies 56 Tungsten logies 57 Tungsten logies 58 Tungsten logies 58 Tungsten logies	
USE3 DED3 YLD3 DOWN3 NLAB3	PTIME3 PCS3 MCH3 ETCH3A ETCH3B CAP3 POW3	USE4 DED4 YLD4 DOWN4 NLAB4 MCH4 RATE4 POW4	USES DEDS YLDS DOWNS NLABS LAPS LAPS PCSS PCSS PTIMES RATES LAPS PLALS	DAYHR5 FLR5 /rnd USE6 DED6 YLD6 DOWN6 NLAB6
1 [1-Y 0-N] 0 [1-Y 0-N] 99.0\$ 10.0\$	30.00 min/batch 20 \$6,000 /sta \$70 /liter \$30 /liter 1.00 l/batch 0.00 kW		1 [1-Y 0-N] 90.0% 15.0% 1.00 1.00 10.0% by wgt 2 5 40.00 min/batch 1.0 um/hr \$53 /liter 3.50 liter/hr 320 hrs	8,640 hrs/yr 400 sqft/ste 10N - MICROSCOPY 1 [1-Y 0-N] 0 [1-Y 0-N] 95.0% 5.0%
Process In Use? Dedicated Investment Process Yald Average Equipment Downtime Direct Laborers Per Station	Load/Unload and Rinse Time Pleces Per Batch Machine Cost Etchant Cost Etchant Disposal Cost Machine Etchant Capacity Machine Space Requirement	PROCESS RELATED FACTORS - LASER TRIMMING Process I Use?  Dedicated Investment Process Yield 99.0 Average Equipment Downtime 10.0 Direct Laborers Per Station 1.00 Machine Cost \$6,000 Trimming Rate 1.00 Machine Power 0.00 Building Space Requirement 100	PROCESS RELATED FACTORS - LAPPING Process In Use? Dedicated Investment Process Yield Average Equipment Dountime Direct Laborers Per Station Lapped Material Removal No of Lapping Steps Pleces Per Batch Load/Unload and Clean Wafers Average Lapping Rate Lapping Slurry Cost Lapping Slurry Usage Rate Lapping Slurry Usage Rate Lapping Plate Life	Available Lapping Time 8,640 hrs/yr Building Space Requirement 400 sqft/st PROCESS RELATED FACTORS - INSPECTION - MICROSCOPY Process In Use? 1  1-Y 0= Dedicated Investment 0  1-Y 0= Process Yield 95.04 Average Equipment Downtime 5.04 Direct Laborers Per Station 1.00

2nd Quarter 1994

					OMCH1 OPOW1	ODAREA2 OTFLOW2 ODRATE2 OMCH2	OCTIME3 OCHEM3 OCTIME4	OCTIMES OWHEELS OMCHS OPWRS	* cxc. dep. 6 lap
PTIME6 INSP6 MCH6	POW6 FLR6	IVITY USE7 DED7 YLD7 DOWN7 NLAB7	PTIME7 INSP7 MCH7 POW7	FLR7	/sta kw	sqcm slm g/hr k\$/sta	hrs /pc hrs	hrs /ea /sta KW	WAGE SALARY ILAB BENI DAYS HRS CRR ELIFE BLIFE
min/batch /sta	kW sqft/sta	RMAL CONDUCTIVITY [1-x 0-N] USE7 [1-x 0-N] DED7 XLD7 DOWN NLAB	min/batch /sta kW	sqft/sta ertmate	\$65,774	60.80 2,743 1.14 \$71	0.18 \$5.00 0.01	111.11 \$869 \$11,939	/hr /yr /hr yrs yrs months
15,00 100% \$50,000	0.10	CTION - THERMAL 1 [1-X 0 [1-Y 95.0% 5.0% 1.00		50	0°0	0.00	00.0	0.00 \$0 \$0 0.00	\$13.33 \$50,000 1.00 35.0\$ 8.00 8.00 5.00 20.00
Average Inspection Time Percent Inspection Machine Cost	Machine Power Building Space Requirement	PROCESS RELATED FACTORS - INSPECTION Process In Use? Dedicated Investment Process Yield Average Equipment Downtime Direct Laborers Per Station	Average Inspection Time Percent Inspection Machine Cost Machine Power	Building Space Requirement OPTIONAL INPUTS	Surface Preparation Machine Cost Machine Power	Duct Flow attion Ipment	Process Cycle Time Chemical Requirement Laser Trimming Process Cycle Time	Lapping Lapping Time Lapping Plate Cost Lapping Machine Cost Lapping Machine Power	EXOGENOUS COST FACTORS Direct Wages Indirect Salary Indirect.Direct Labor Ratio Benefits on Wage and Salary Working Days per Year Working Hours per Day (*) Capital Recovery Rate Capital Recovery Period Building Recovery Life

Price of Electricity Price of Natural Gas Price of Building Space Price of Cooling Water	\$0.050 \$6.50 \$100 \$0.03	/kWh /MBTU /sqft /100 gal	ELEC GAS PBLD WATER
Auxiliary Equipment Cost Equipment Installation Cost Maintenance Cost	15.0% 35.0% 8.0%		AUX INST MNT
REGRESSION CONSTANTS, COEFFICIENTS,	AND	EXPONENTS	
-Surface Preparation- Machine Cost Constant	1, 334	MCH1A	
Machine Cost Capacity Coef Machine Power Constant	3,222	MCH1B PWR1A	
Machine Power Capacity Coef	1.00	PWRIB	
-Deposition- Diamond Density (q/cc)	3,52	DENS	
[H]/[CH3] Quality Constant [H]/[CH3] Quality Coefficient	133	QUAL3	
	1.77	QUAL3B QUAL3C	
QMult. Coefficient QMult. To Exponent	0.00	QM2A QM2B	
[H]/[CH3] Qual. Baseline	10.15	QUAL3D	
. Expansion Factor Cons	4.76	VEFA2	
Vol. Expansion Factor Coeff.1 Vol. Expansion Factor Coeff.2	4.46	VEFB2 VEFC2	
×	-3.91	GRA2	
Growth Rate "a" Expon. 3 Growth Rate "a?" Expon. 3	2.91	GRB2	
Expon.	23.97	GRD2	
Growth Rate "R2" Expon. 3	-334.80	GRE2	
<pre>Enthalpy (kcal/mol) - C2H2 Enthalpy (kcal/mol) - C0</pre>	54.19 -26.42	HF2A HF2B	
Machine Cost Wafer Area Coef	161.46	MCH2Y	
Machine Cost Area Exponent Machine Cost Area Constant	1.00	MCH2Z MCH2X	
-Etching-			
•			
Machine Cost Constant Machine Cost Capacity Coef	2,719	MCH5A MCH5B	
hine P	-0.75	PWRSA	
Machine Power Capacity Coef Tool Cost Constant	1.00	PWR5B TOOL5A	

0.92 TOOL5B 2.90 TOOL5C Tool Cost Capacity Coef
Tool Cost Capacity Exponent 

# IBIS ASSOCIATES, INC. TECHNICAL COST MODEL (C) 1993 . RESTRICTED RIGHTS LEGEND

Use, duplication, or disclosure by the Government is subject to restrictions as set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013

# 

0.1	COMBUSTION CVD TCM: IBIS ASSOCIATES, INC	DEPOSITION .	N Copyright (c)	1991 v4.0	
investment		per piece	per year	percent	investment
	variable COSI ELEMENIS Material Cost	\$16.730.22	\$16.730.220	88.24	
		\$788.29	\$788,287	4.2%	
	Utility Cost	\$60.42	\$60,418	0.3%	
	FIXED COST ELEMENTS				
\$98,661	Equipment Cost	\$270.36	\$270,364	1.48 \$1,3	\$1,386,834
\$0		\$0.00	0\$	ő	\$0
\$25,000		\$95.04	\$95,038		\$1,950,000
		\$260.21	\$260,207		
	Overhead Labor Cost	\$253.44	\$253,436	1.3%	
	Cost of Capital	\$501.75	\$501,755	2.68	
\$123,661	TOTAL FABRICATION COST	\$18,959.72	\$18,959,725	100.04 \$3,3	\$3,336,834
		\$103.94	/ sqcm		
	INTERMEDIATE CALCULATIONS				
	Process In Use	-	[1-Y 0-N]	PR02	
	Cumulative Yield	69.78		CYLD2	
	Effective Production Volume	1,436	/yr	ENUM2	
	Machine Powor	~	×	DAPOW2	
	Duct Area (A Inf.)	08.09	SOCE	DAREA2	
		8.80	<b>.</b> 5	DDIAM2	
	Quality Multiplier	1.07	[0.4 <x<5]< th=""><th>QMULT2</th><th></th></x<5]<>	QMULT2	
	Strain Rate (a)	638	1/sec	STRN2A	
	Volume Expansion Factor	7.42	,	VOLEF2A	
	Gas Velocity	5,578	cm/s	SPEEDZA	
	Total Gas Flow Rate	2,743	s Im	TFLOWZA	
		1,403	ET S	CF LOWER	
	CAYGO GES LION NACE	966 11	mr a	AF LUMEA	
		71.34	ъ	MASS2	
	Deposition	17.7	µ/hr	LINDEP2	
		1.1	g/hr	MASDEP 2	
	Deposition Time	28.29	nrs	CTIMEBZ	
		7	<b>8</b> Tu	C1 IMEN	
	Runtime for One Station	1267		RTIME2	
	Number of Parallel Stations	12.67		NSTAT2	
	Total Oxygen Gas Volume	5,044	SCM/pc	XGAS2	
**********	Total Carbon Gas Volume	5, 296	SCM/pc	CARGAS2	
	Oxygen Gas Cost	\$1,059	/bc	COSTA2	
	Acetylene Gas Cost Carbon Capture Factor	\$10,592	/bc	COSTB2	
				i :	
	Combustion Enthalpy Change	1447	kJ/mol	ENTH2	
		•	10 <b>6</b> 1 CE	Mr was	

ENERGY1 SPACE1 MCH1 POW1

0.959 kWh/pc 250 sqft

Energy Requirement Building Space/Station Machine Cost

/sta

\$65,774

3

19.2

Machine Power

CTIME1 RTIME1 NSTAT1

3 min/pc 3% 0.03

Process Cycle Time Runtime for One Station Number of Parallel Stations

SUB1 LIFE1

182.4 sq cm \$43.45 /pc 1.00 cycle

Substrate Area New Substrate Cost Substrate Useful Life

**AREA**1

ENUM1

1,511 /yr

PRO1 CYLD1

1.00 [1-Y 0-N] 66.2%

Cumulative Yield

Process In Use

INTERMEDIATE CALCULATIONS

Effective Production Volume

IEQUIP1 AEQUIP1

/sta /sta

\$88,795 \$9,866

Installed Equipment Cost Auxiliary Equipment Cost

TINT1 BINT1 WINT1

\$825 /yr \$0 /yr \$95 /yr \$68,858 /yr

Tooling Annuity Building Annuity Working Annuity

Equipment Annuity

EINT1

9.00

\$647 \$0

0.18 0.58 1.28 2.08

\$41 \$324 \$820 \$1,364

\$0.65 \$0.00 \$0.04 \$0.32 \$0.32 \$0.82

Equipment Cost Tooling Cost Building Cost

FIXED COST ELEMENTS

Maintenance Cost Overhead Labor Cost

Cost of Capital

100.0%

\$69,778

\$69.78

TOTAL FABRICATION COST

Copyright (c) 1991 v4

COMBUSTION CVD TCM: SURFACE PREPARATION

IBIS ASSOCIATES, INC.

per year percent

per piece

94.1%

\$65,660

\$850

\$65.66 \$0.85 \$0.07

Material Cost Direct Labor Cost Utility Cost

VARIABLE COST ELEMENTS

EINT2 TINT2 BINT2 WINT2	
4444	
***	•
Equipment Annuity \$344,666 Tooling Annuity \$220,114 Working Annuity \$18,394,945	
Annuity Annuity Annuity Annuity	
Equipment Tooling Building Working	

IEQUIP2 AEQUIP2

\$96,012 /sta \$10,668 /sta

Installed Equipment Cost Auxiliary Equipment Cost

COOL2 ENERGY2 SPACE2

836 kW 31.7 gal/min 119,343 gal/pc 126 kWh/pc 1,500 sqft

Conbustion Power Cooling Water Flow Rate Cooling Water Requirement Energy Requirement Building Space/Station

CPOW? WATER2

REC2 XRENT2 GTANK2

/mo/tank /year /sta

\$0 /sta \$350 /mo/t \$4,200 /ye \$71,120 /

Recycle Equipment Cost Liquid Oxygen Tank Rental Gas Storage Equipment Rent Machine Cost

MCH2B

COMBUSTION CVD TCM: IBIS ASSOCIATES, INC.	ETCHING	copyright (c)	1991 v4.0		COMBUSTION CVD TCM: SER TRIMMING IBIS ASSOCIATES, INC.	ER TRIMMING	Copyright (c) 1991 v4.0	1991 v4.	0
TANGLE COMPANY	per piece	per year	percent	investment	The state of the s	per piece	per year	r percent	investment
VANIABLE COSI ELEMENIS Material Cost	\$3.98	\$3,980	29.0%		- VARIABLE COSI ELEMENIS Material Cost	\$0.00	\$0	0.0	
Direct Labor Cost	\$4.62	\$4,616	33.7%		Direct Labor Cost	\$0.33	\$331	47.84	
Utility Cost	\$0.00	80	0.0		Utility Cost	\$0.00	0\$	0.0	
FIXED COST ELEMENTS -		11111111111	-		- FIXED COST ELEMENTS -			-	
Equipment Cost	\$0.16	\$160	1.24	\$9,000	Equipment Cost	\$0.01	\$11	1.78	\$9,000
Tooling Cost	\$0.00	80	0.0	\$0	Tooling Cost	\$0.00	\$0	0.0	\$0
Building Cost	\$0.04	\$45	0.3%	\$10,000	Building Cost	\$0.00	\$3	0.54	\$10,000
Maintenance Cost	\$0.14	\$135	1.04		Maintenance Cost	\$0.01	\$10	1.4%	
Overhead Labor Cost	\$4.45	\$4,452	32.54		Overhead Labor Cost	\$0.32	\$319	46.1%	
Cost of Capital	\$0.32		2.48		Cost of Capital	\$0.02	\$18	2.78	
TOTAL FABRICATION COST	\$13.71	\$13,712	100.04	\$19,000	TOTAL FABRICATION COST	\$0.69	\$693	100.04	\$19,000
TAMES OF THE PART	-		! ! !		TAME DATOR TAME OF TAXABLE				
INTERMEDIATE CARCOMATIONS					INTERMEDIATE CANCULATIONS	•		•	
Process In Use	1.00 (1=Y	(1-x 0-n)	PR03		Process In Use	1.00	[1-Y 0-N]	PRO4	
Cumulative Yield	79.64		CYLD3		Cumulative Yield	80.4		CYLD	
Effective Production Volume	1,256	/yr	ENUM3		Effective Production Volume	1,244	/yr	ENUM	
Total Etchod Thickness	3.810	E	E.T.II T.K.3		BELL CLOSS RECOOLS	0.01	hrs/bc	CT IME4	
State Trachers		11 /m / m	FORTES		Buntime for One Station			RT TME.4	
012	9.0	hrs/22	CH1165		manufacture of the property of	֡֝֓֞֜֜֜֝֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֡֓֓֡֓֡֓֡֓		ATATOM.	
Buntime for One Station	9.10	nts/pc	CILMES		Number of Farattet Stations	5		TUTON	
Number of Parallel Stations	60-0		NSTATS						
	1				Energy Requirement	0	kWh/pc	ENERGY 4	
Chemical Requirement	\$5.00	/bc	CHEM3		Building Space/Station	100	sq ft	SPACE4	
Energy Requirement	0	kWh/pc	<b>ENERGY3</b>						
Building Space/Station	100	sq ft	SPACE3			\$8,100	/sta	IEQUIP4	
11					Auxiliary Equipment Cost	\$900	/sta	AEQUIP4	
	\$8,100	/sta	IEQUIP3						
Auxiliary Equipment Cost	006\$	/sta	<b>AEQUIP3</b>		Equipment Annuity	\$15	/yr	EINT	
					Tooling Annuity	80	/yr	TINIT	
Equipment Annuity	\$204	/yr	EINT3		Building Annuity	\$7	/yr	BINT4	
Tooling Annuity	\$0	/yr	TINIS		Working Annuity	\$671	/yr	WINT	
Building Annuity	\$103	/yr	BINT3						
Working Annuity	\$13,405	/yr	WINT3		***************************************	**********	**********	*******	*********
医医皮肤 化氯化物 医水杨二氏 医多种氏性 医多种氏性 医多种性性 医多种性性 医多种性 医多种性	********	_		医克勒氏性试验检 医多种性性结核 医多种性性性性性性性					

Part place   Par	### Per piece   Per year percent investment   Per piece   Per year percent   Investment   Per piece   Per year percent   Investment   Per piece   Per year percent   Investment   Per piece   Per year percent   Investment   Per piece   Per year percent   Investment   Per piece   Per	IBIS ASSOCIATES, INC.		Copyright (c)	1991 v4.0		IBIS ASSOCIATES, INC.		copyright (c)	1991 V4.0	
TATION COST \$725.01 \$725,009 43.24  Labor Cost \$586.32 \$586,316 34.94  Lilty Cost \$5.79 \$5.79 \$0.34  Lilty Cost \$13.50 \$13,503 \$0.84 \$71,634  Labor Cost \$74.41 \$74,415 \$17,465  Labor Cost \$188.50 \$188.50 \$11.24  Labor Cost \$188.50 \$188.50 \$11.24  Labor Cost \$188.50 \$1.678.07 \$10.04 \$160,000  ATION COST \$1,678.08 \$1,678.07 \$10.04 \$160,000  ATION COST \$1,678.08 \$1,678.07 \$10.04 \$10.00  ATION COST \$1,678.08 \$1,678.09 \$10.00  ATION COST \$1,678.08 \$1,678.09 \$10.00  ATION COST \$1,678.08 \$1,678.09 \$10.00  ATION COST \$1,678.08 \$10.00  ATION COST \$1,678.09 \$10.00  ATION COST \$10.00	ATIONS	Uablable Cost of Substance	per piece		percent		THE STATE OF STREET	per piece	per year	percent	investment
### Signature	### Sign of the cost si	~		\$725 000	43 28		7	80 00	OS	400	
				\$586,316				\$5.25	\$5.249	39.98	
ATIONS AT	State   Stat			\$5,786				\$0.00	\$1	0.0	
ATIONS AT	ATIONS AT				1						
Equipment Cost \$13.50 \$13,503 0.84 \$71,634  Toolling Cost \$77.41 \$77,415 0.44 \$160,000  Building Cost \$77.54 \$77,405 0.44 \$160,000  Street Silver Cost \$17.47 \$17,465 1.04 \$160,000  Street Silver Cost \$17.47 \$17,465 1.04 \$160,000  Street Silver Cost \$1,678.08 \$1,678,077 100.04 \$603,707  CALCULATIONS  FABRICATION COST \$1,678.08 \$1,678,077 100.04 \$603,707  CALCULATIONS  Frocess In Use Captual Lapped \$11.21 um Hill Capture Columniative Yield \$12.31 /yr ENUMS  For One Station \$17.31	Equipment Cost \$11.50 \$13.503 0.64 \$71.634  Toolling Cost \$7.44 \$74.415 4.44 \$372.073  Building Cost \$7.54 \$7.54 0.0.44 \$372.073  Building Cost \$7.54 \$7.54 0.0.44 \$372.073  Building Cost \$7.54 \$7.54 0.0.44 \$160.000  Machine Power \$188.50 \$1.678.00 \$1.04 \$160.000  Setup Time \$1.678.08 \$1,678.077 \$100.04 \$603,707  CALCULATIONS  FABRICATION COST \$1,678.08 \$1,678,077 \$100.04 \$603,707  CALCULATIONS  FABRICATION COST \$1,678.08 \$1,678.077 \$100.04 \$603,707  CALCULATIONS  FABRICATION COST \$1,678.09 \$1,678.07 \$100.04 \$603,707  CALCULATIONS  FABRICATION COST \$1,678.09 \$1,678.09 \$100.04 \$1	FIXED COST ELEMENTS					FIXED COST ELEMENTS				
Pooling Cost   \$74.41   \$74,415   4.4\$   \$372,073	Tooling Cost   \$74.41   \$74,415   4.48   \$372,073			\$13,503	0.8	\$71,634		\$1.52	\$1,519	11.64	\$75,000
### Building Cost \$7.54 \$7,540 0.4\$ \$160,000 #################################	### Building Cost \$7.54 \$7,540 0.4% \$160,000   #### Building Cost \$17.47 \$17,465 1.0% \$1.00   #### Exercise Cost \$188.50 \$188,502 11.2% \$1.00   #### Cost of Capital \$1,678.08 \$1,678.07 100.0% \$603,707   #### Exercise In Use			\$74,415	4.48	\$372,073		\$0.00	0\$	0.0	9
### ### ### ### ### ### ### ### ### ##	### ### ### ### ### ### ### ### ### ##			\$7,540		\$160,000		\$0.03	\$25	0.24	\$5,000
Cost of Capital   \$59.54   \$1.24	CALCULATIONS  FABRICATION COST		٠,	\$17.465				\$0.65	\$648	4.94	
CALCULATIONS  PROCESS IN USE  CALCULATIONS  PROSE  CUMULative Vield  11.21	CALCULATIONS  Process In Use  CALULATOR PROCESS  PROCESS IN Use  CALULATIONS  CALULATIONS  CALULATIONS  CALULATIONS  CALULATIONS  CALULATIONS  CALULATION	Overhead Labor Cost		\$188,502			Overhead Labor Cost	\$5.06	\$5,062	38.54	
### CALCULATIONS  CALCULATIONS  Process In Use	FABRICATION COST \$1,678.08 \$1,678.077 100.0\$ \$603,707  CALCULATIONS  Process In Use  CLOUNDISTICATIONS  Process In Use  Process In Use  CLOUNDISTICATIONS  FROST  Cumulative Yield  1,231 /yr  Setup Time  1,231 /yr  Lapping Time  1,331 /yr  Lapping Time  1,331 /yr  Lapping Plate Cost  Sping Plate Cost  Sping Plate Cost  Sping Plate Cost  Sping Plate Life  1,231 /yr  Sping Plate Cost  Sping	Cost of Capital		\$59,540	3.5%		Cost of Capital	\$0.63	\$634	4.84	
CALCULATIONS  Process In Use  Cumulative Yield  1,231 /yr  Eurum5  Production Volume  1,231 /yr  Setup Time  1,33 hrs/batch  Lapping Time  111.11 um  HLAP5  Setup Time  111.11 hrs/batch  CTIME5B  Parallel Station  3.77  PROFESA  Lapping Plate Cost  spping Plate Cost  spping Plate Life  14.2 kW  Machine Power  4.2 kW  Acconsumption  4.2 kW  Acconsumption  4.2 kW  Machine Cost  811,939 / sta  MCH5  Hard Space/Station  400 sq ft  Space/Station  41,7443 /yr  FINT5  Building Annuity  817,214 /yr  FINT5  Building Annuity  81,7463 /yr  WINT5	CALCULATIONS Process In Use Cumulative Yield Cumulative Y	TOTAL FABRICATION COST	;	\$1,678,077	100.04	\$603,707	TOTAL FABRICATION COST	\$13.14	\$13,138	100.00	\$80,000
CALCULATIONS PROCESS IN USE Process In Use R1.24 R1.24 In.231 /yr EMUM5 Froduction Volume R1.231 /yr EMUM5 Froduction Volume R231 /yr In.45 Froduction Volume R4.24 Froduction R4.	CALCULATIONS PROCESS In Use Process In Use R1.24 R231 /yr FRO5 Cumulative Yield L231 /yr FRUM5 Froduction Volume L231 /yr FRUM5 Froduction Volume L331 /yr FRUM5 Setup Time L331 /yr Lapping Time L331 /yr LAZF5 RAILES RAI										
1.00 [1=Y 0=N] PRO5 81.24 CYLD5 11,231 /yr ENUM5 111.11 um HLAP5 11.33 hrs/batch CTIME5A 111.11 hrs/batch CTIME5B 3.77 RTIME5 428.00 11.11 1/pc GRIT5 94 kWh/pc ENERGY5 511,939 /sta BRA5 400 sq ft SPACE5 516,118 /sta IEQUIP5 517,214 /yr EINT5 594,865 /yr TINT5 517,463 /yr WINT5	CYLDS ENUMS LCH HLAPS CCTIMESA CCTIMESA CCTIMES RTIMES NSTATS PLAS WHEELS PLAS WHEELS PLAS WHEELS PLAS WHEELS PLAS WHEELS SPLAS ENERGYS MCHS SPACES S										
81.24 CYLD5 1,231 /yr ENUM5 111.11 um HLAP5 113.3 hrs/batch CTIME5A 111.11 hrs/batch CTIME5B 3.77 CTIME5B 3.77 RTIME5 14 pcs PLAS 14.2 kW PREL5 11.11 1/pc GRIT5 4.2 kW PWR5 94 kWh/pc ENERGY5 \$11,939 /sta MCH5 \$11,939 /sta IEQUIP5 \$11,791 /sta IEQUIP5 \$1,721 /sta AEQUIP5 \$17,214 /yr EINT5 \$17,463 /yr BINT5 \$1,548,534 /yr WINT5	CYLDS HLAPS HLAPS CTIMESA CTIMESB RTIMES NSTATS PLAS WHEELS PLAS WHEELS PLATS GRITS GRITS GRITS FLATS GRITS FLATS GRITS FLATS FLATS GRITS FLATS GRITS FLATS	Process In Use		(1-Y 0	PR05			1.00		PR06	
11.23 /yr ENUM5 11.33 hræ/batch CTIME5A 111.11 hræ/batch CTIME5B 33.77 RTIME5 3.77 RTIME5 3.77 RTIME5 11.11 l/pc PLAT5 11.11 l/pc RTIME5 5428.00 11.11 l/pc RTIME5 541.939 /ata PWR5 511,939 /ata PWR5 511,939 /ata PWR5 511,939 /ata PWR5 511,939 /ata RCH5 510,118 /ata RCH5 51,791 /ata REQUIP5 51,791 /ata REQUIP5 51,794 /yr RINT5 51,463 /yr BINT5 51,548,534 /yr WINT5	ENUMS  HIAPS  CTIMESA CTIMESB RTIMES NSTATS PLAS WHEELS PLATS GRITS PLATS GRITS PLATS PRES PRES ENERGYS MCHS SPACES IEQUIPS AEQUIPS AEQUIPS AEQUIPS AEQUIPS AEQUIPS BINTS BINTS WINTS	Cumulative Yield			CYLDS		Cumulative Yield	90.38		CYLD6	
111.11 um HLAP5 1.33 hrs/batch CTIME5A 111.11 hrs/batch CTIME5B 3.77	HLAPS  CTIMESA CTIMES RTIMES NSTATS PLAS WHEELS PLATS GRITS PMRS ENERGYS MCHS SPACES IEQUIPS AEQUIPS AEQUIPS RINTS BINTS BINTS WINTS	Effective Production Volume	-		ENUMS			1,108	/yr	ENUM6	
11.11 hrs/batch CIMESA 111.11 hrs/batch CIMESA 3.77 RIMES 3.77 RIMES 428.00 PLAS 11.11 1/pc RRITS 11.11 1/pc GRITS 4.2 kW PWRS 511,939 /ata MCHS 511,939 /ata MCHS 510,118 /ata RCHS 517,214 /yr EINTS 517,214 /yr EINTS 517,463 /yr BINTS 51,548,534 /yr WINTS	tch crimes tch crimes RTIMES NSTATS PLAS WHEELS PLATS GRITS GRITS PMRS ENERGYS MCHS SPACES IEQUIPS AEQUIPS AEQUIPS RINTS BINTS WINTS	thickness of Metorial I among		!	304.10		E CEE COCCAG	20		7.000	
11.11 hrs/batch CTIMESB 3174 RTIMES RTIMES AS69 /ea PLAS NSTATS 428.00 PLATS 11.11 1/pc PLATS 4.2 kW PWRS GRITS 4.2 kW PWRS S11,939 /sta MCHS 511,939 /sta MCHS 517,214 /yr EINTS 517,214 /yr EINTS 517,463 /yr BINTS 51,548,534 /yr WINTS	teh CIIMESB RTIMES NSTATS NSTATS PLAS WHEELS PLATS GRITS GRITS GRITS MCHS SPACES SPACES LEQUIPS AEQUIPS BINTS BINTS BINTS BINTS BINTS BINTS BINTS BINTS	Dedder retreated to seemoning	7	L. 1			BETT BIRGS CROTTS	67.0		Carred	
1374 TIMES 3.77 SINESS 3.77 SINESS 3.77 SINESS 428.00 PLAS 11.11 1/pc PLATS 4.2 kW PWRS 4.2 kW PWRS 511,939 /sta PWRS 400 sq ft SPACES 516,118 /sta PRCES 517,214 /yr EINTS 594,865 /yr TINTS 517,463 /yr BINTS 51,548,534 /yr WINTS	CCO CTIMES NSTATS PLAS WHEELS PLATS GRITS GRITS PWRS ENERGYS MCHS SPACES IEQUIPS AEQUIPS AEQUIPS FINTS FINTS BINTS WINTS WINTS	DELL CUIDO	:	nrs/parch	CITALIA		Nuntime tor one statement			DAME IN	
\$869 /ea PLA5  \$869 /ea PLA5  14 pcs WHEEL5  428.00 PLAT5  11.11 1/pc GRIT5  4.2 kW PWR5  \$11,939 /sta PWR5  \$10,118 /sta RCH5  \$1,791 /sta REQUIP5  \$17,214 /yr EINT5  \$17,463 /yr HINT5  \$1,548,534 /yr WINT5	NETATS PLAS WHEELS PLATS GRITS GRITS GRITS ENERGYS MCHS SPACES IEQUIPS AEQUIPS TINTS BINTS BINTS WINTS	emil pridded	777	nrs/Dat	CTIMESE		Number of Paralles Stations	0.10		DIVICE	
\$869 /ea PLAS 14 pcs WHEELS 428.00 11.11 1/pc GRITS 4.2 kW PWRS 94 kWh/pc ENERGYS \$11,939 /eta MCHS 400 sq ft SPACES \$16,118 /eta REQUIPS \$17,214 /yr EINTS \$17,463 /yr BINTS \$1,548,534 /yr WINTS	NSTAID PLAS WHEELS PLATS GRITS FACTS ENERGYS MCHS SPACES IEQUIPS AEQUIPS FINTS	Nunctime for one station	•		KIIMED			•	7 7 7 7 7	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	
Lapping Plate Cost         \$869         /ea         PLAS           Lapping Plate Life         14         pcs         WHEELS           of Plates Required         428.00         PLATS           Slurry Consumption         11.11         1/pc         GRITS           Machine Power         4.2         kW         PWRS           Energy Requirement         94         kWh/pc         ENERGYS           Machine Cost         \$11,939         /sta         MCHS           iding Space/Station         400         sq ft         SPACES           iled Equipment Cost         \$16,118         /sta         AEQUIPS           iary Equipment Cost         \$1,791         /sta         AEQUIPS           Tooling Annuity         \$17,214         /yr         TINTS           Building Annuity         \$17,463         /yr         WINTS	PLAS WHEELS PLATS GRITS PWRS ENERGYS MCHS SPACES IEQUIPS AEQUIPS EINTS FINTS BINTS BINTS WINTS	Number of Parallel Stations			NSTATS		Energy Requirement Entlding Space/Station	9 6	KWIN/pc	SPACE	
Lapping Plate Cost of Plates Required of Plates Required for Plates f	WHEELS PLATS GRITS PRATS ENERGYS MCHS SPACES IEQUIPS AEQUIPS FINTS TINTS BINTS WINTS	Tach details		,	94.10		morane (sande furnitue	3	, , , , , , , , , , , , , , , , , , ,		
of Plates Required 428.00 PLATS Slurry Consumption 11.11 1/pc GRITS Slurry Consumption 11.11 1/pc GRITS Slurry Consumption 11.11 1/pc GRITS Slurry Consumption 4.2 kW PWRS Energy Requirement 94 kWh/pc ENERCYS Machine Cost \$11,939 /sta McCHS Accellang Space/Station 400 sq ft SPACES Lary Equipment Cost \$16,118 /sta REQUIPS Lary Equipment Cost \$17,7214 /yr EINTS TOOLING Annuity \$17,214 /yr Bullding Annuity \$17,463 /yr WINTS Morking Annuity \$1,548,534 /yr WINTS	PLATS GRITS PMRS ENERGYS MCHS SPACES IEQUIPS AEQUIPS TINTS TINTS BINTS WINTS WINTS	Laborang Flace Cost		900	FLA3			867 500	, et a	AGTINGT	
Slurry Consumption 11.11 1/pc GRIT5  Machine Power 4.2 kW Achine Power 94 kWh/pc ENERGY5 Machine Cost \$11,939 /sta MCH5 Iding Space/Station 400 sq ft SPACE5 Ided Equipment Cost \$16,118 /sta IEQUIP5 Lary Equipment Cost \$17,7214 /yr EINT5 Tooling Annuity \$17,214 /yr EINT5 Building Annuity \$17,463 /yr BINT5 Working Annuity \$1,548,534 /yr WINT5	GRITS PWR5 ENERGY5 MCH5 SPACE5 IEQUIP5 AEQUIP5 EINT5 TINT5 BINT5 WINT5			3.	21111			27 500	/sta	AFORTIDE	
Machine Power 4.2 kW PWR5  Energy Requirement 94 kWh/pc ENERGY5  Machine Cost \$11,939 /sta MCH5  Iding Space/Station 400 sq ft SPACE5  Iled Equipment Cost \$16,118 /sta IEQUIP5  Lary Equipment Cost \$17,7214 /yr EINT5  Tooling Annuity \$17,214 /yr EINT5  Working Annuity \$17,463 /yr BINT5  Working Annuity \$1,548,534 /yr WINT5	PWR5 ENERGY5 MCH5 SPACE5 IEQUIP5 AEQUIP5 EINT5 TINT5 BINT5 WINT5			1/pc	GRITS						
Power         4.2 kW         PWR5           enent         94 kWh/pc         ENERGY5           Cost         \$11,939 / sta         MCH5           sation         400 sq ft         SPACE5           Cost         \$16,118 / sta         IEQUIP5           Cost         \$1,791 / sta         AEQUIP5           cuity         \$17,214 / yr         EINT5           nuity         \$17,463 / yr         BINT5           nuity         \$1,548,534 / yr         WINT5	PWR5 ENERGY5 MCH5 SPACE5 IEQUIP5 AEQUIP5 EINT5 TINT5 BINT5 WINT5 WINT5			•	ı		Equipment Annuity	\$1,936	/yr	EINT6	
Cost \$11,939 /sta MCH5 Cost \$11,939 /sta MCH5 ation 400 sq ft SPACE5 Cost \$16,118 /sta IEQUIP5 Cost \$1,791 /sta AEQUIP5 nulty \$17,214 /yr EINT5 nulty \$17,463 /yr BINT5 nulty \$1,548,534 /yr WINT5	ENERGYS MCHS SPACES IEQUIPS AEQUIPS EINTS TINTS BINTS WINTS WINTS	Machine Power		KW	PWR5		Tooling Annuity	80	/yr	TINTE	
Cost \$11,939 /sta MCH5 stion 400 sq ft SPACE5  Cost \$16,118 /sta REQUIP5 Cost \$1,791 /sta AEQUIP5 nulty \$17,214 /yr EINT5 nulty \$17,463 /yr BINT5 nulty \$1,548,534 /yr WINT5	MCH5 SPACE5 IEQUIP5 AEQUIP5 FINT5 TINT5 BINT5 WINT5	Energy Requirement		kWh/pc	<b>ENERGY5</b>			\$59	/vr	BINT6	
stion         400         sq ft         SPACE5           Cost         \$1,791         /sta         IEQUIP5           Cost         \$1,791         /sta         AEQUIP5           nulty         \$17,214         /yr         EINT5           nulty         \$17,463         /yr         BINT5           nulty         \$1,548,534         /yr         WINT5	SPACES IEQUIPS AEQUIPS EINTS TINTS BINTS WINTS WINTS	Machine Cost		/sta	MCH5			\$11,143	/yr	WINT6	
Cost \$16,118 /sta IEQUIP5 Cost \$1,791 /sta AEQUIP5 nulty \$17,214 /yr EINT5 nulty \$17,463 /yr BINT5 nulty \$1,548,534 /yr WINT5	IEQUIPS AEQUIPS EINTS TINTS BINTS WINTS WINTS	Building Space/Station		sq ft	SPACE5						
Cost \$16,118 /sta Cost \$1,791 /sta nulty \$17,214 /yr nulty \$94,865 /yr nulty \$17,463 /yr nulty \$1,548,534 /yr		•		1			\# \$	**********	**********		**********
Cost \$1,791 /sta nulty \$17,214 /yr nulty \$94,865 /yr nulty \$17,463 /yr nulty \$1,548,534 /yr				/sta	IEQUIP 5						
\$17,214 /yr \$94,865 /yr \$17,463 /yr \$1,548,534 /yr				/sta	<b>AEQUIP</b> 5						
\$17,214 /yr \$94,865 /yr \$17,463 /yr \$1,548,534 /yr				,	1						
Annuity \$94,865 /yr Annuity \$17,463 /yr Annuity \$1,548,534 /yr		Equipment Annuity		/yr	EINTS						
Annuity \$17,463 /yr Annuity \$1,548,534 /yr		Tooling Annuity		/yr	TINTS						
\$1,548,534 /yr		Building Annuity		/yr	BINTS						
		Working Annuity		/yr	WINTS						
		******	*****		* *******	*********					

1994
arter
4 Que
2nd

Per place   Per	COMBUSTION CVD TCM: INSPECTION - THERMAL, IBIS ASSOCIATES, INC. Copyright	INSPECTION -	~	conductivity (c) 1991 v4.0	0	COMBUSTION CVD TCM: COST SUMMARY IBIS ASSOCIATES, INC.	OST SUMMANY	Copyright (c) 1991 v4.0	1991 v4.0	
\$0 0.04	VADIADID COCT DIGMENTS	per piece	יי ו	percent	investment	The state of the s	per piece		•	investment
11.08   \$75,000   Equipment Cost   \$287,723   \$1.48   \$1.725   \$287,723   \$1.48   \$1.725   \$287,723   \$1.48   \$1.725   \$287,723   \$1.48   \$1.725   \$2.165   \$2.000   Equipment Cost   \$102.72   \$102,716   \$0.48   \$2.165   \$2.000   Equipment Cost   \$102.72   \$102,716   \$0.48   \$2.165   \$1.38   \$2.165   \$2.16	Material Cost Material Cost Direct Labor Cost Utility Cost	\$0.00 \$4.99 \$0.00	\$0 \$4,986 \$1	0.0\$ 38.7\$ 0.0\$		al Cost or Cost ty Cost	\$17,524.87 \$1,390.63 \$66.28	\$17,524,870 \$1,390,635 \$66,279	84.5% 6.7% 0.3%	
11.84   \$75,000   Equipment Cost   \$287.72   \$1.44   \$1,725   \$1.45   \$1,725   \$2.60	FIXED COST ELEMENTS					FIXED COST ELEMENTS				
Storement   Stor	Equipment Cost	\$1.52	\$1,519	11.8%	\$75,000	pment	\$287.72	\$287,723	1.48	\$1,725,129
10.00	Tooling Cost	\$0.00	\$0	0.0	\$0		\$74.41	\$74,415	0.4	\$372,073
1.34   1.34	Building Cost	\$0.03	\$25		\$5,000		\$102.72	\$102,718	0.5%	\$2,165,000
100.04	Maintenance Cost	\$0.65	\$648			Maintenance Cost	\$279.44	\$279,438	1.38	
100.0\$ \$80,000   TOTAL FABRICATION COST \$20,747,994   100.0\$ \$4,262	Overhead Labor Cost Cost of Capital	\$5.06 \$0.63	\$5,062 \$629	39.3%		Overhead Labor Cost Cost of Capital	\$457.65 \$564.26	\$457,654 \$564,263	2.28	
PRO7   SUPEMARY INFORMATION   Part Name 6 in. substrate	TOTAL FABRICATION COST	\$12.87	\$12,871	100.04	\$80,000		\$20,747.99	\$20,747,994	100.0	\$4,262,202
PRO7	INTERMEDIATE CALCULATIONS					SUMMARY INFORMATION				
CYLD7  CYLD7  Total Direct Laborers  21,650 sqft  44.3 Med  Total Capital Investment  SA.3 Med  CTIME7  Area Cost	Process In Use		(1-Y 0-N)	PR07		Part Name 6	in. substru	ite		
ENUMY  Total Capital Investment \$4.3 Met  Total Capital Investment \$4.3 Met  Total Capital Investment \$4.3 Met  NSTAT7  COST Per Carat \$64.81 /ct  ENERGY7  Surface Preparation \$1 \$66 \$2  Surface Preparation \$21 \$10.42  AEQUIP7  AEQUIP7  ELCHING \$0 \$1.042  ELCH	Cumulative Yield			CXID)		Total Direct Laborers	13.70	/shift		
CTIME7	Effective Production Volume	1,053	/vr	ENUM		Total Floor Space	21,650	sqft		
Notice   State   Sta			•				\$4.3	¥		
NSTAIT   NSTAIT   NSTAIT   NSTAIT   NSTAIT   NSTAIT   NSTAIT   COST PET CAIST   \$64.81 /ct	Process Cycle Time	0.25	hrs	CTIME?						
NSTAT7   Cost Per Cdrat   \$64.81 /ct	Runtime for One Station	104		RT IME 7		Area Cost	\$113.74	/sdcm		
ENERCYT         Operation         Equipment         Material         Labor           SPACE7         Surface Preparation         \$1         \$6         \$2           IEQUIP7         Surface Preparation         \$10,042         \$4         \$9           AEQUIP7         Laser Trimming         \$0         \$4         \$9           EINT7         Inspect - Microscopy         \$2         \$10         \$10           BINT7         Inspect - Thermal Cond'vity         \$2         \$0         \$10           WINT7         Total         \$288         \$17,525         \$1,848         \$1           Total         \$20,748	Number of Parallel Stations	0.10		NSTAT7		Cost Per Carat	\$64.81	/ct		
### SPACE7  Surface Preparation \$1 \$66 \$2  Surface Preparation \$270 \$16,730 \$1,042  AEQUIP7	Energy Requirement		kwh/pc	ENERGY7		Operation	Equipment	Material	Labor	Other
IEQUIP7	Building Space/Station		sq ft	SPACE7						
### ##################################	And Annual Princes for the Party of the Part	600	, 41,	243.000		Surface Preparation	T & C	999	25	25
EINT7 Leaser Trimming \$0 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1 \$1	Anwiller Equipment Cost	87 500	/ ST. B.	TEGOLE!		DEPOSITE TON	0174	910,/30	21, U42	186
EINT7  Inspect - Microscopy \$2 \$775  SINT7  BINT7  WINT7  Total \$288  \$17,525 \$1,848  \$1	1000 Disputing Institute			A STONE		ŀ	O W	r C	, r	, c
TINT7 Inspect - Microscopy \$2 \$0 \$10 BINT7 Inspect - Thermal Cond'vity \$2 \$0 \$10 WINT7 Total \$288 \$17,525 \$1,848 \$1	Equipment Annuity	\$1.936	/vr	EINT		•	\$14	\$725	8775	\$165
BINT7 Inspect - Thermal Cond'vity \$2 \$10 \$10 WINT7 Total \$288 \$17,525 \$1,848	Tooling Annuity	\$0	\.	TINIT		Inspect - Microscopy	\$2	0\$	\$10	\$1
WINT7  Total \$288 \$17,525 \$1,848  Total \$20,748	Building Annuity	\$59	/yr	BINT7		Inspect - Thermal Cond'vity	\$2	\$0	\$10	\$1
Total \$288 \$17,525 \$1,848	Working Annuity	\$10,877	/yr	WINT					191111111	
Total =				, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	******	Total	\$288	\$17, 525	\$1,848	\$1,087
		********			*********	Total	\$20,748			